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Technology Readiness Levels for Partitioning and Transmutation of Minor Actinides in Japan

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Outline

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- Technology Readiness Levels (TRL)
  - What is TRL?
  - Why use TRL?
  - Examples of TRL usage
- TRL for P&T Technology in Japan
  - MA transmutation systems
  - MA partitioning processes
  - MA-bearing fuels
- Technology pathway discussion with TRL
- Summary

Background

- The second check and review on the P&T technology
  - made by the Japan Atomic Energy Commission (JAEC) in 2008-2009, and the final report has been issued in April, 2009
- Future research and development plan on the P&T technology should be made
- The Research Committee on P&T and MA Recycle, Atomic Energy Society of Japan (AESJ)
  - noticed the usefulness of Technology Readiness Levels (TRL) approach
  - to support the planning of research and development on P&T technology

Objectives

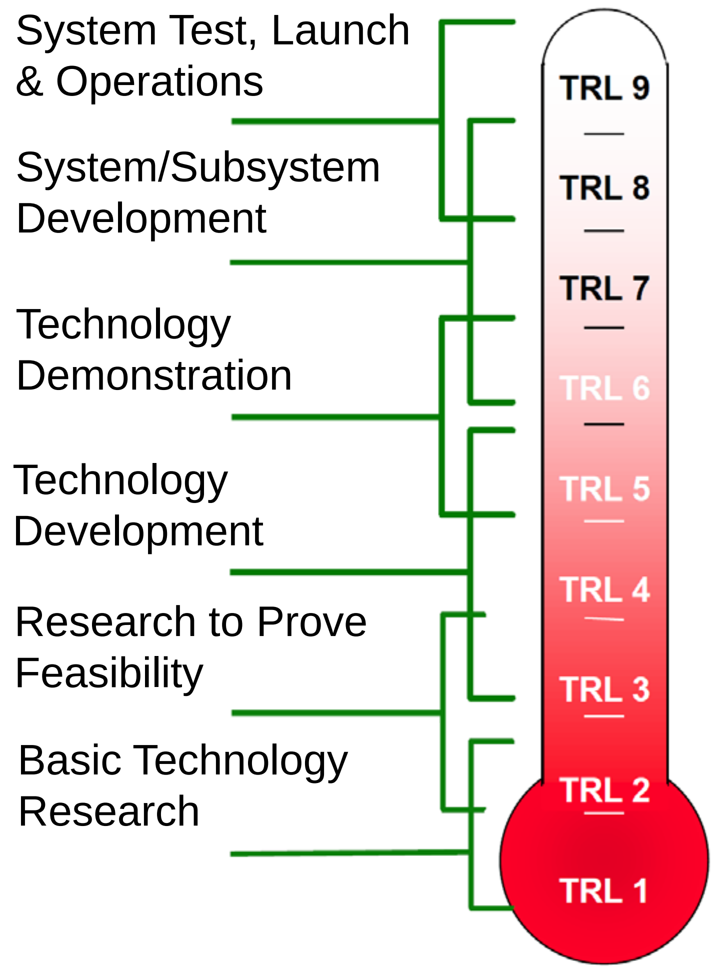
- Technology Readiness Levels (TRL) approach
  - » was used to provide a quantitative assessment for the maturity of the P&T technology in Japan
- The present TRL evaluation was
  - » made by the Research Committee on P&T and MA Recycle, AESJ
  - » <u>independent of</u> the Fast Reactor Cycle System Technology Development Project (FaCT Project) in Japan
- The main objective of the present TRL evaluation is
  - » <u>Not</u> to provide absolute quantitative values of TRL
  - » <u>But</u> to discuss how to conduct the research and development of the P&T technology

What is TRL?

- TRL is a systematic metric/measurement system that supports assessments of the maturity of a particular technology
  - » From a new concept that is viable based on first principles assessment
  - » To full maturity of long-term routine operations of commercial plant
  - » The intermediate steps are defined based on the logical progression of the research and development towards demonstration and deployment

TRL for NASA Space Activities

- The TRL approach has been used on-and-off in NASA* space technology planning for many years
- The technology maturation process model for NASA space activities
  - » Definition of 9 levels
    - – from basic principles at TRL 1
    - – to operations at TRL 9
  - » The exit criteria at each TRL level



John C. Mankins, NASA White Paper “Technology Readiness Levels” April 6, 1995.

* National Aeronautics and Space Administration

Why use TRL?

- TRL approach provides
  - » a relative measure of where the technology maturity is compared to the end objective of large-scale deployment
- TRL is used as
  - » a program management tool
    - – a common understanding of science and technology exit criteria
    - – a consistent comparison of maturity between different types of technology
    - – a communication tool between technologists and managers

TRL Evaluation in GNEP

- TRL evaluation for
  - Advanced recycling reactor
  - LWR spent fuel processing
  - Waste form development
  - Fast reactor spent fuel processing
  - Fuel fabrication and performance
- TRL definitions used in GNEP

Global Nuclear Energy Partnership technical Integration Office, GNEP-TECH-TR-PP-2007-00020, July 25, 2007.

TRL	Category	Generic Description
9	Proof of Performance	Actual facility proven through successful mission operations
8		Prototype facility completed and qualified through test and demonstration
7		System prototype demonstration in prototypic environment
6	Proof of Principle	System/subsystem model or prototype demonstration in relevant environment
5		Component and/or breadboad validation in a relevant environment
4		Component and/or bench-scale validation in a laboratory environment
3	Concept Development	Analytical and experimental demonstration of critical function and/or proof of concept
2		Technology concepts and/or applications formulated
1		Basic principles observed and formulated

TRL for P&T Technology in Japan

- TRL definitions
  - » Based on the TRL definitions used in GNEP
- Technology included in the present TRL evaluation
  - » Developed in Japan
  - » Developed as international collaboration including Japan
- TRL evaluation for
  - » MA transmutation systems
    - – MA-loaded core of fast reactor
    - – Accelerator driven system
  - » MA recycling technology
    - – MA partitioning processes (aqueous, pyro)
    - – MA-bearing fuels (oxide, metal, nitride)

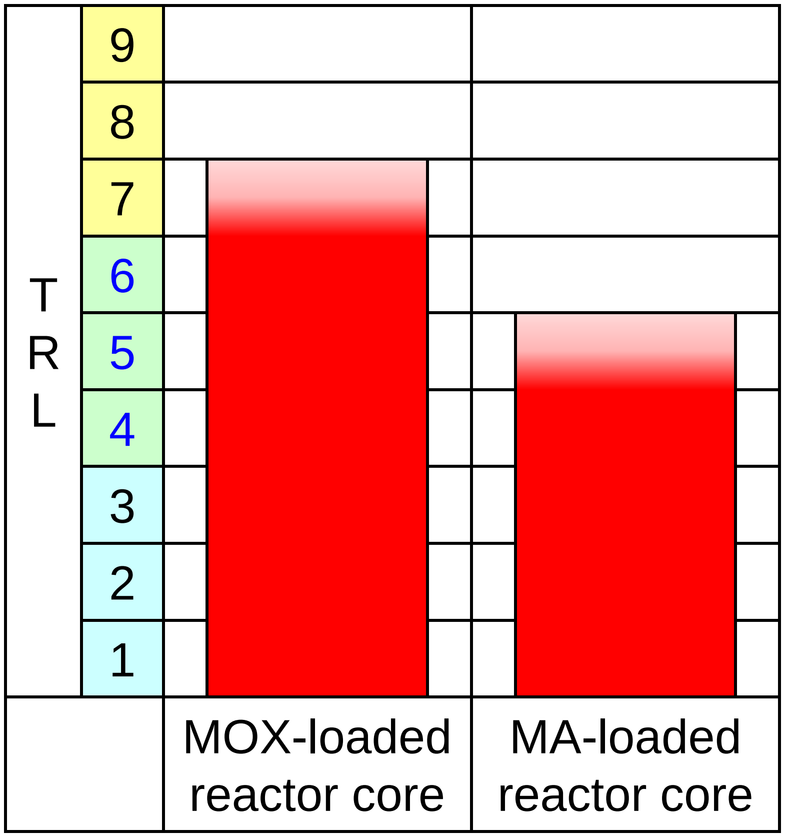
TRL for MA-loaded Core of FR (1/2)

TRL Definitions

TRL	Category	Description
9 :	Proof of Performance	Actual facility proven through successful mission operations :
6	Proof of Principle	Nuclear design for MA-loaded core of prototype reactor
5		Critical experiment with MA Nuclear design for MA-loaded core of experimental reactor
4		MA sample irradiation Nuclear calculation code validation
3	Concept Development	MA nuclear data evaluation Nuclear calculation code development
2		MA nuclear data measurement
1		Basic principles observed and formulated

TRL for MA-loaded Core of FR (2/2)

TRL Evaluation

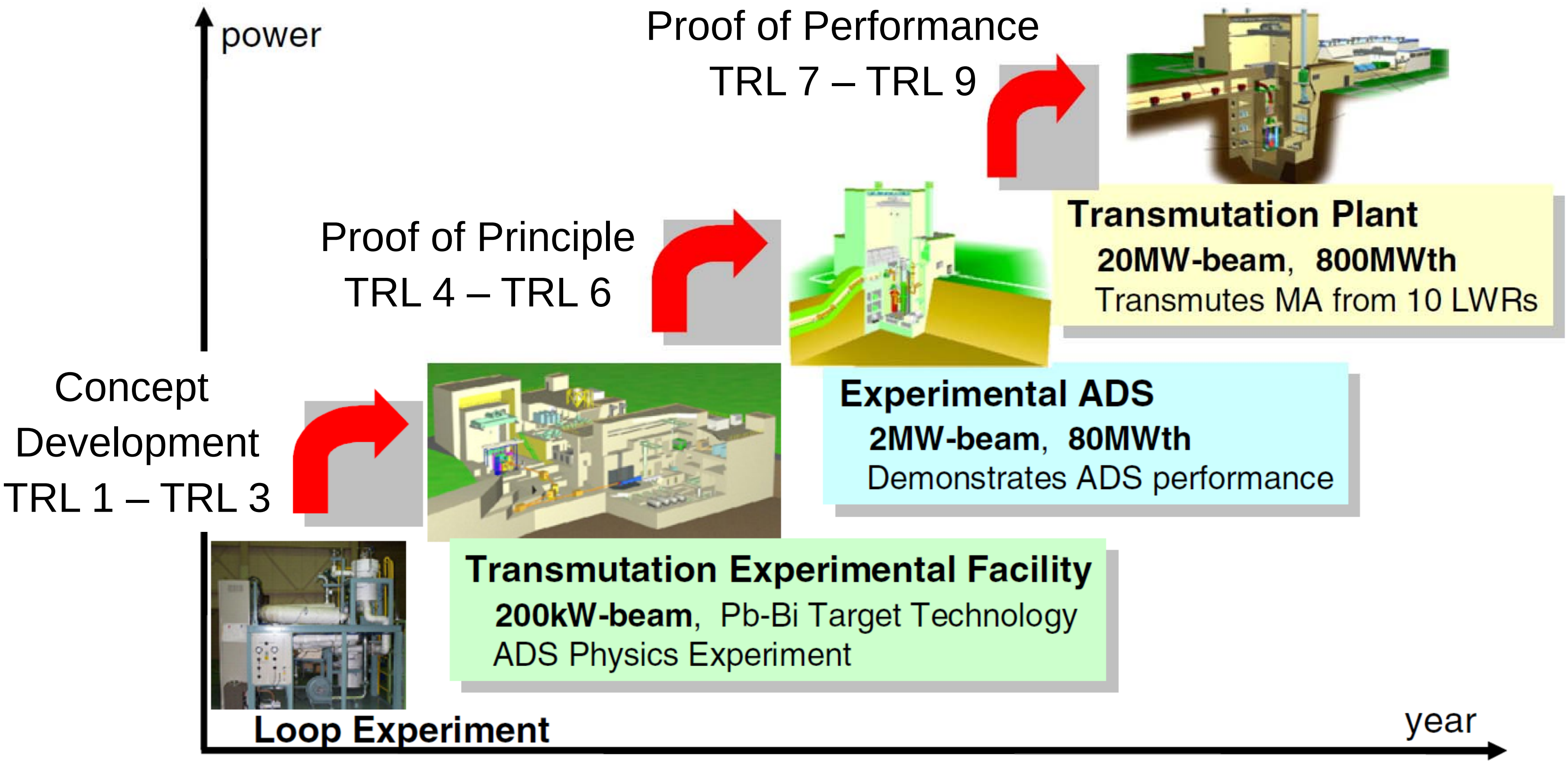


- Not much experience in MA-loaded reactor core
- Several percentages of MA loading influence the core characteristics, which is important in licensing
- On the other hand, critical experiment with several kg of MA is effective, but difficult at the existing experimental facility and will require a new one

- One of the key issues is how nuclear calculation methodology for MA-loaded core would be validated toward TRL 5

TRL for ADS (1/3)

ADS Development Plan



TRL for ADS (2/3)

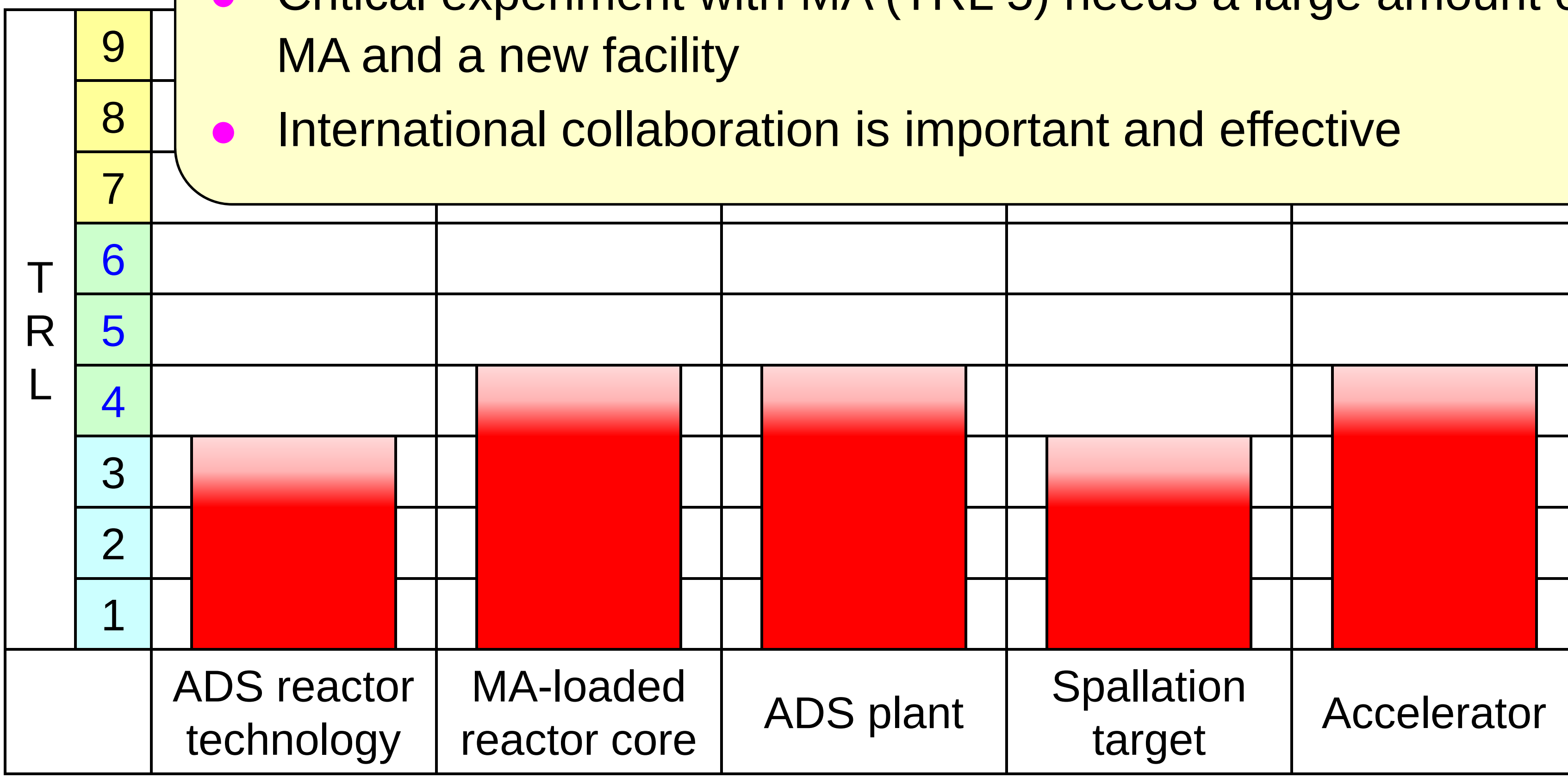
TRL Definitions

TRL	Category	Description
9 :	Proof of Performance	Actual facility proven through successful mission operations :
6	Proof of Principle	Design for MA-loaded prototype ADS
5		Critical experiment with MA; large scale LBE loop experiment; proton beam supply to ADS test facility; spallation target mock-up
4		Nuclear calculation code validation; MA sample irradiation; beam window proton irradiation; shielding experiment/code validation
3	Concept Development	Nuclear calculation code development; MA nuclear data evaluation; LBE loop experiments; target irradiation tests
2		Sub-critical reactor physics; MA nuclear data measurement;
1		Basic principles observed and formulated

TRL for ADS (3/3)

TRL Evaluation

- Technologies in several fields have been developed for ADS
- Critical experiment with MA (TRL 5) needs a large amount of MA and a new facility
- International collaboration is important and effective



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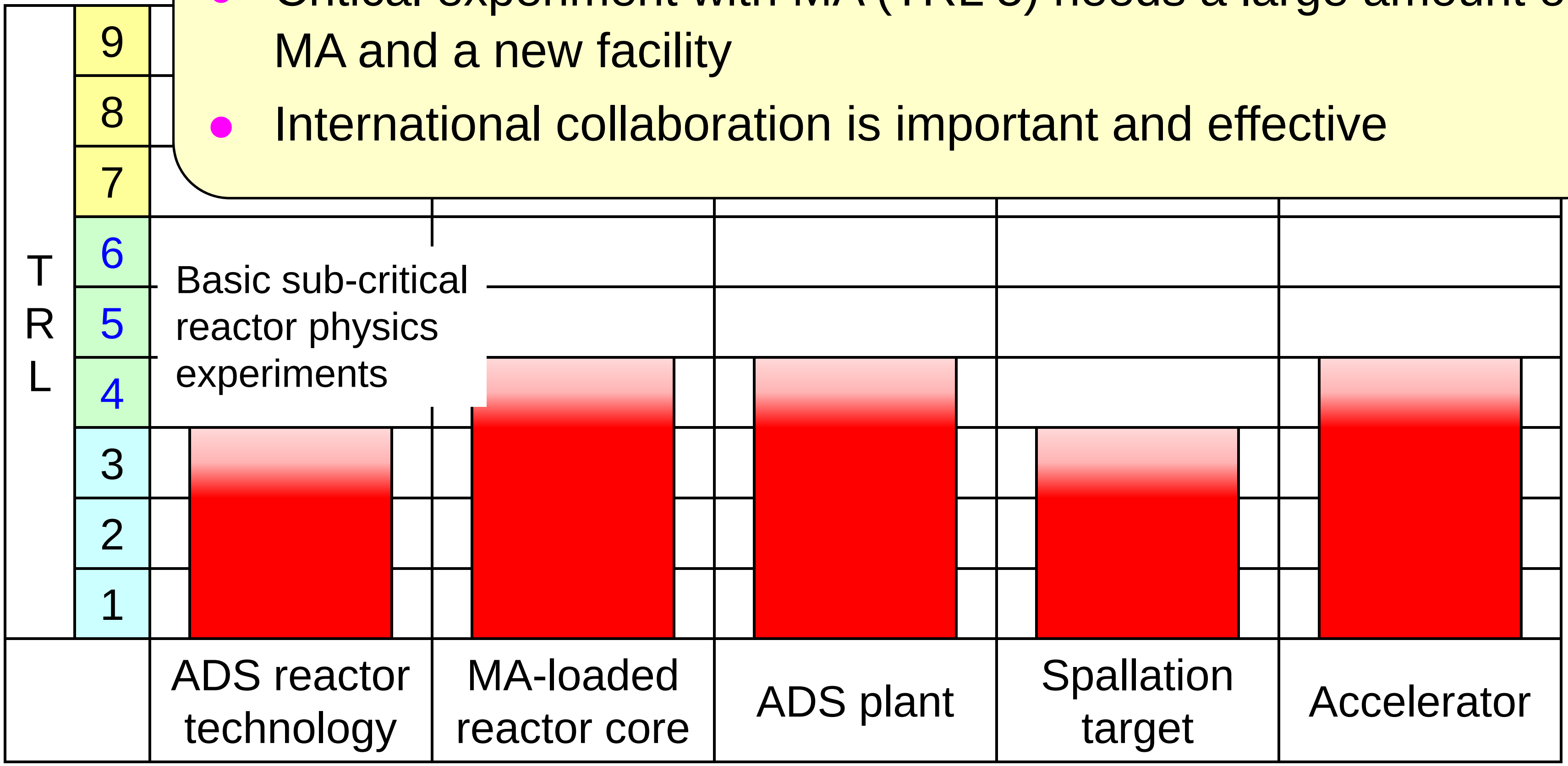

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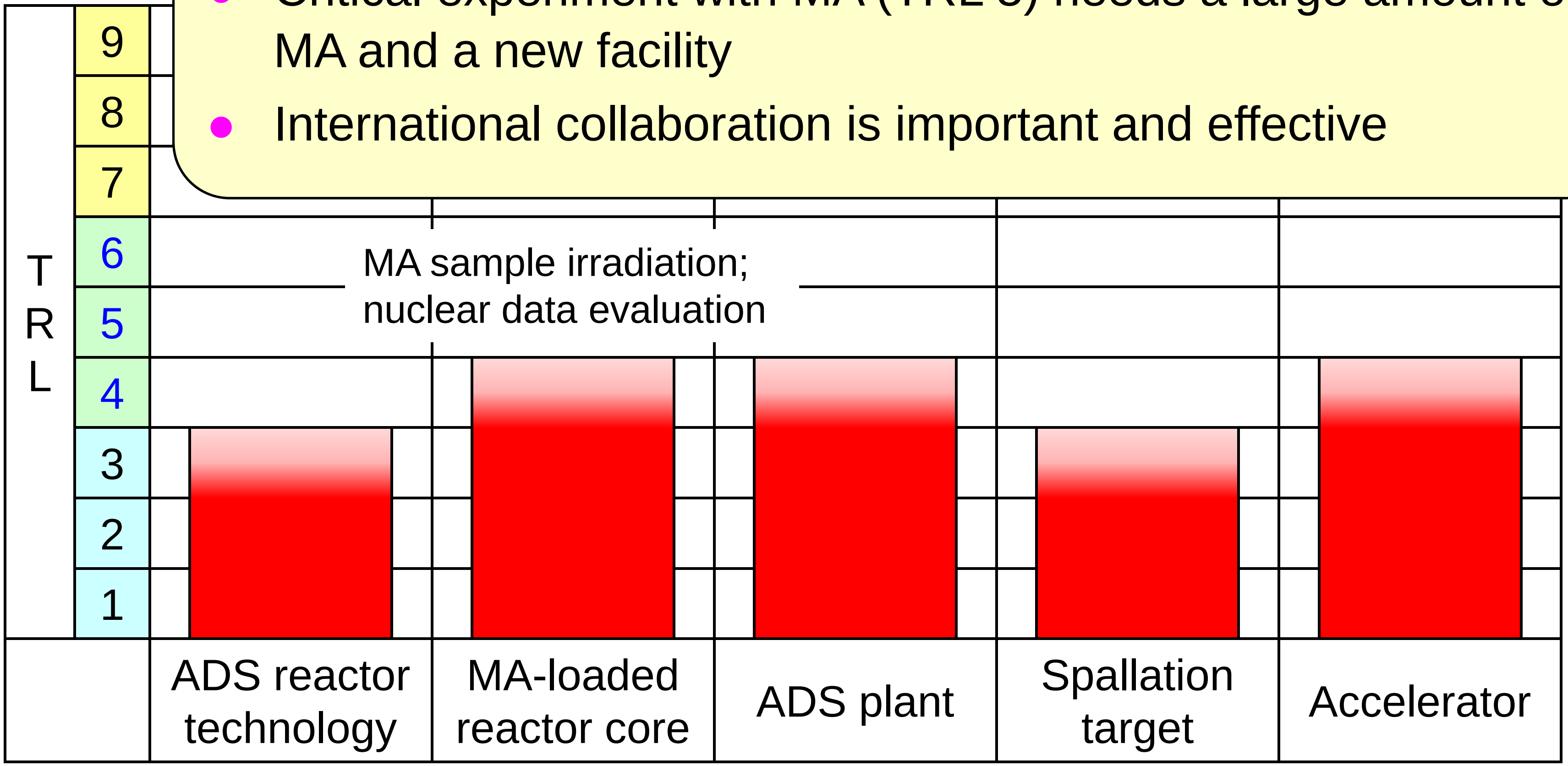

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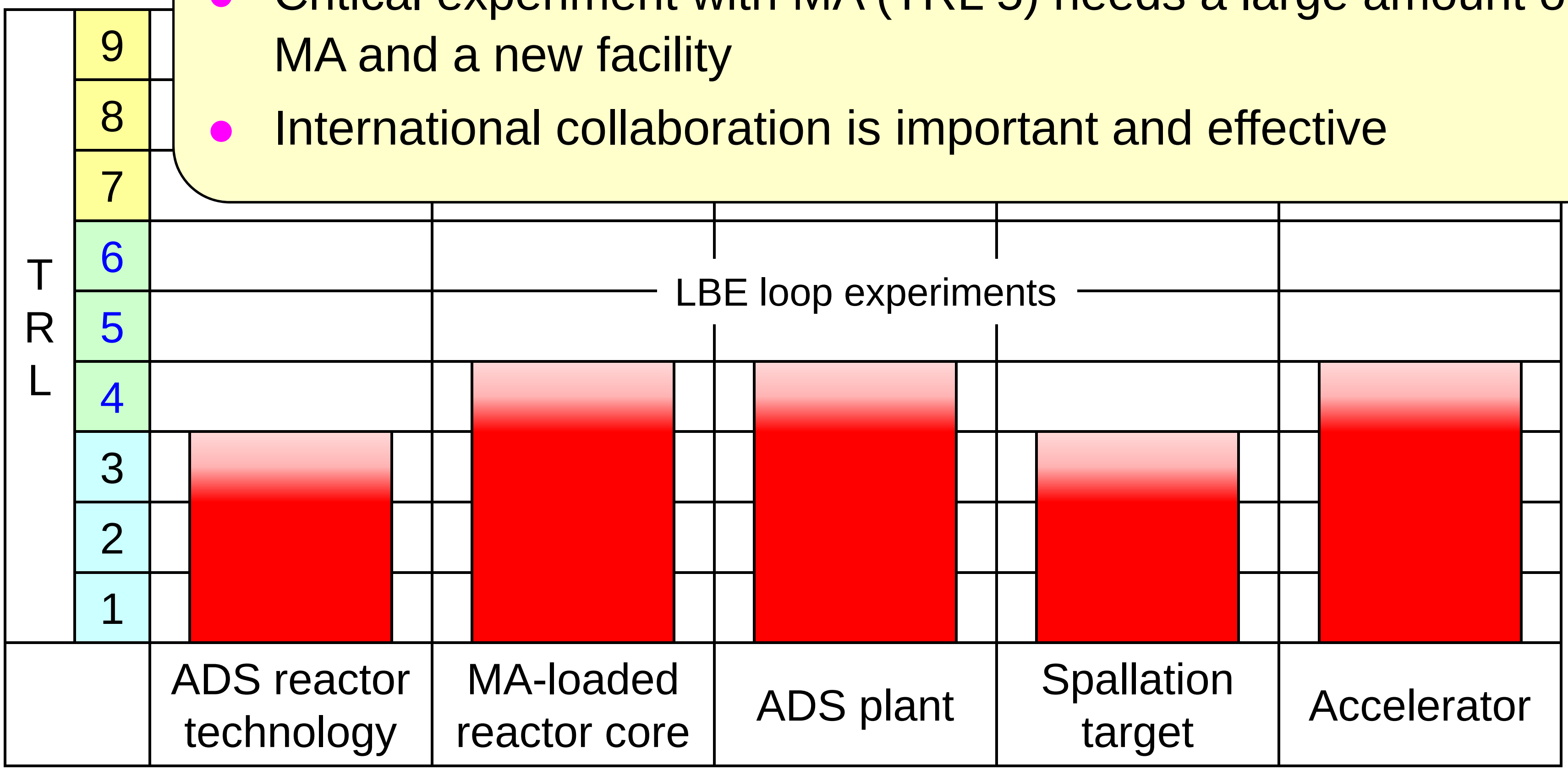

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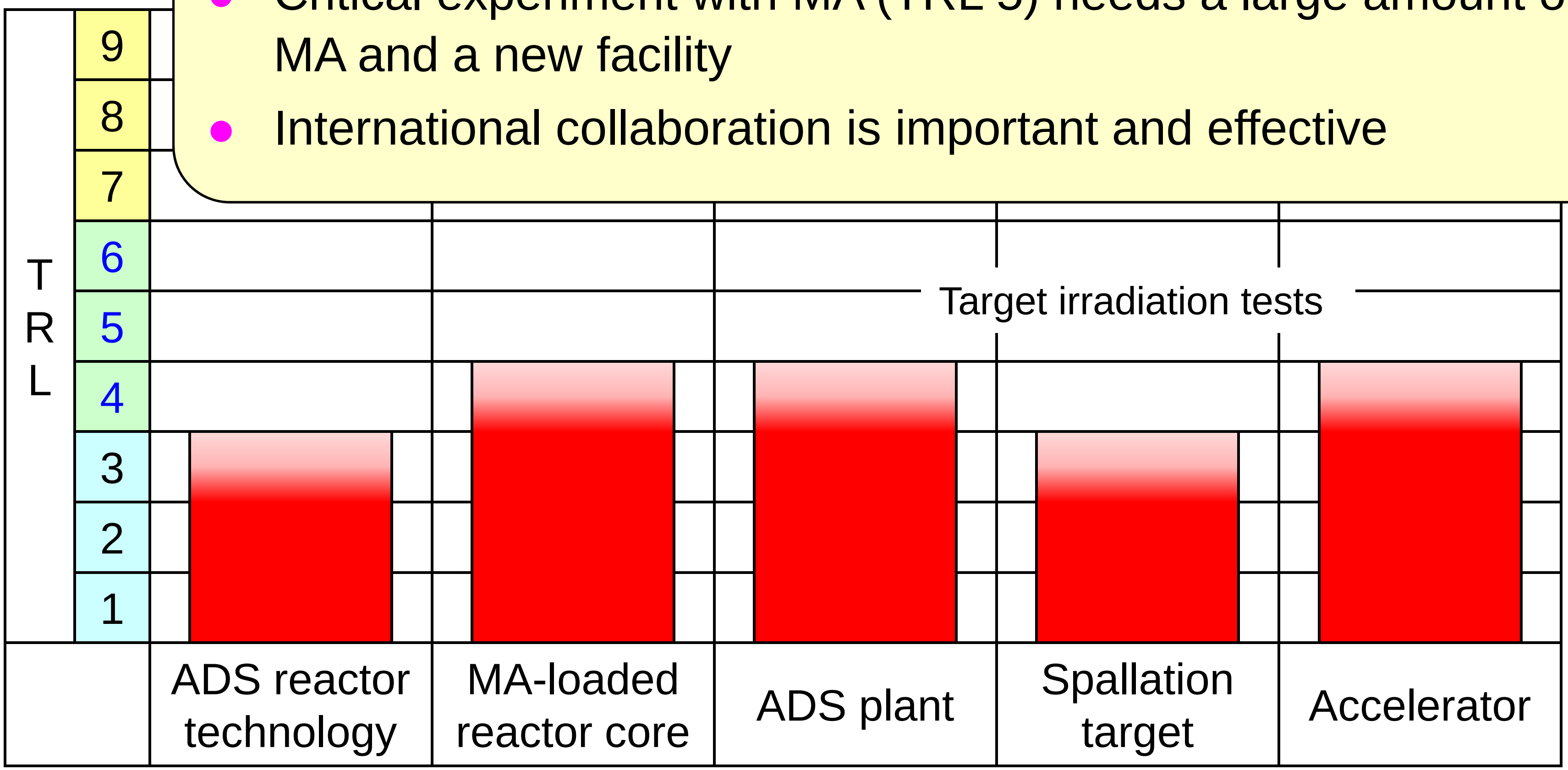

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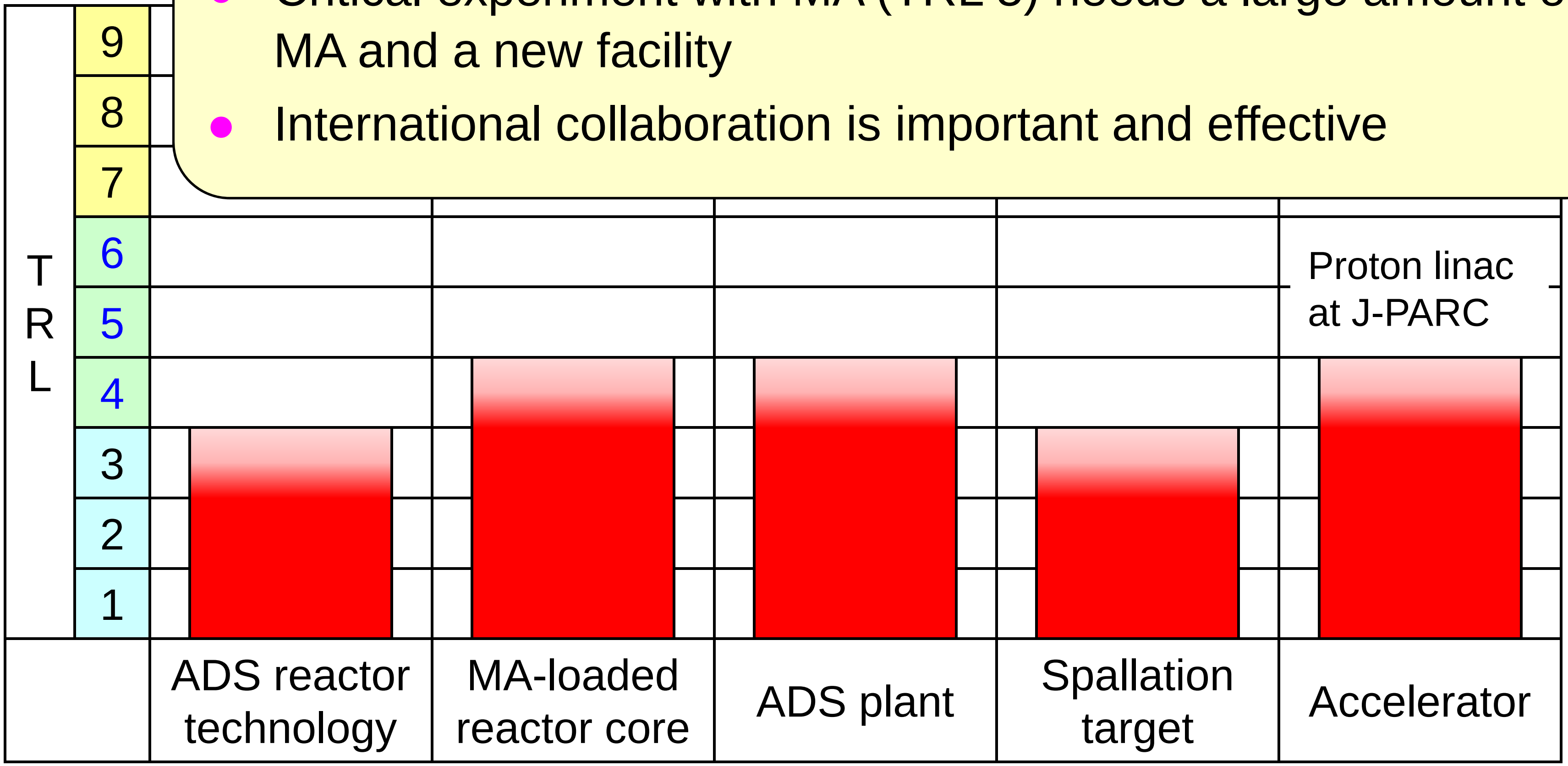

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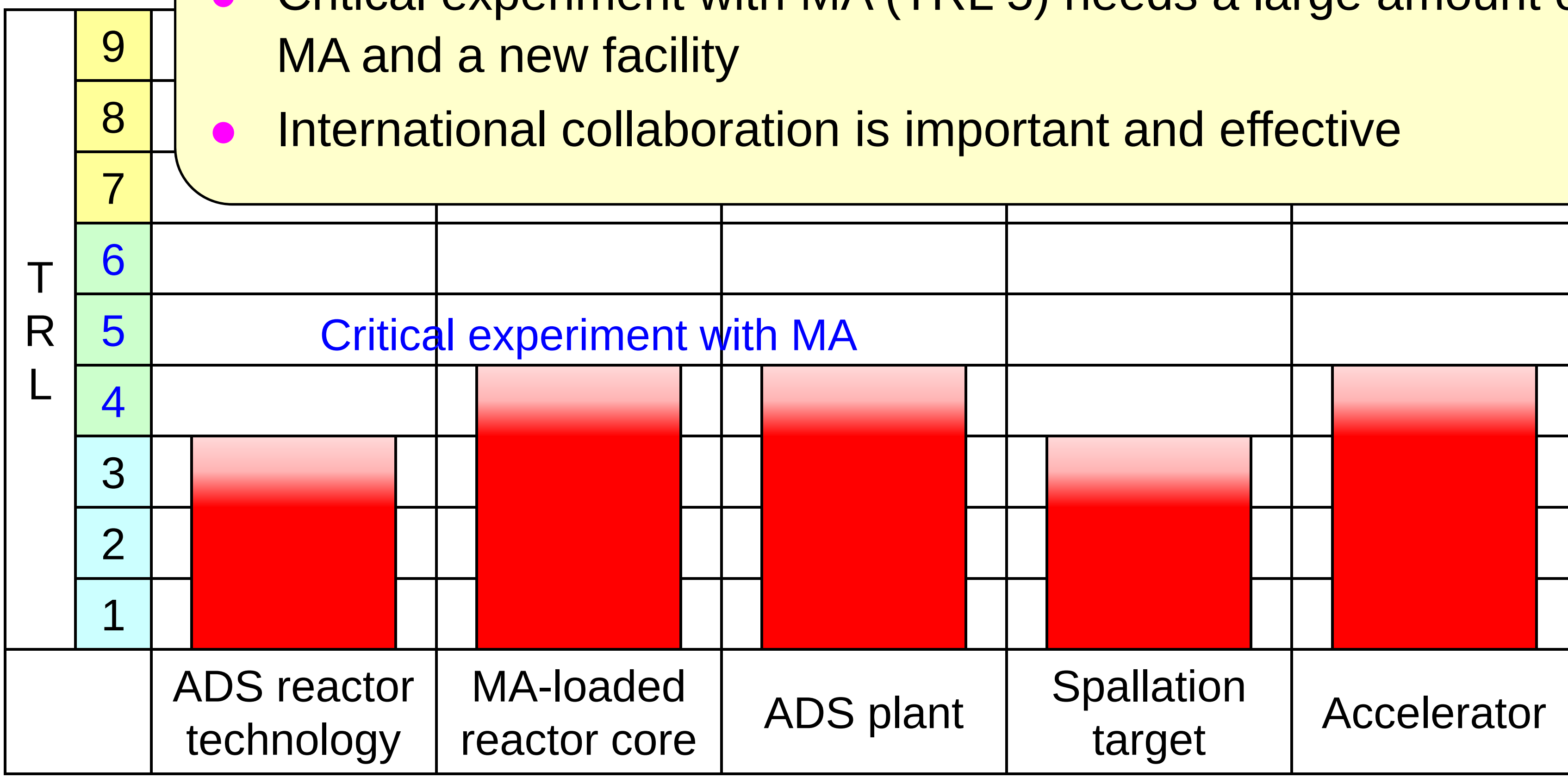

TRL for MA Partitioning Processes (1/2)

TRL Definitions

TRL	Category	Description
9 :	Proof of Performance	Actual facility proven through successful mission operations :
6	Proof of Principle	*Full-scale* unit operations testing with *actual spent fuel* Process equipment design validated
5		*Engineering scale* unit operations testing with *actual spent fuel* Simulation models validated
4		*Engineering scale* unit operations testing with *simulated materials* Separations chemistry models developed
3	Concept Development	*Laboratory-scale* batch testing with *simulated materials* Preliminary testing of equipment design concepts
2		*Bench-scale* batch testing with *simulated materials* Preliminary selection of process equipment
1		Basic principles observed and formulated

TRL for MA Partitioning Processes (1/2)

Full-scale: 1-10 kg-MA/day
Engineering scale: 0.1-10 kg-MA/day
Laboratory-scale: 1-100 g-MA/day
Bench-scale: mg-10 g-MA

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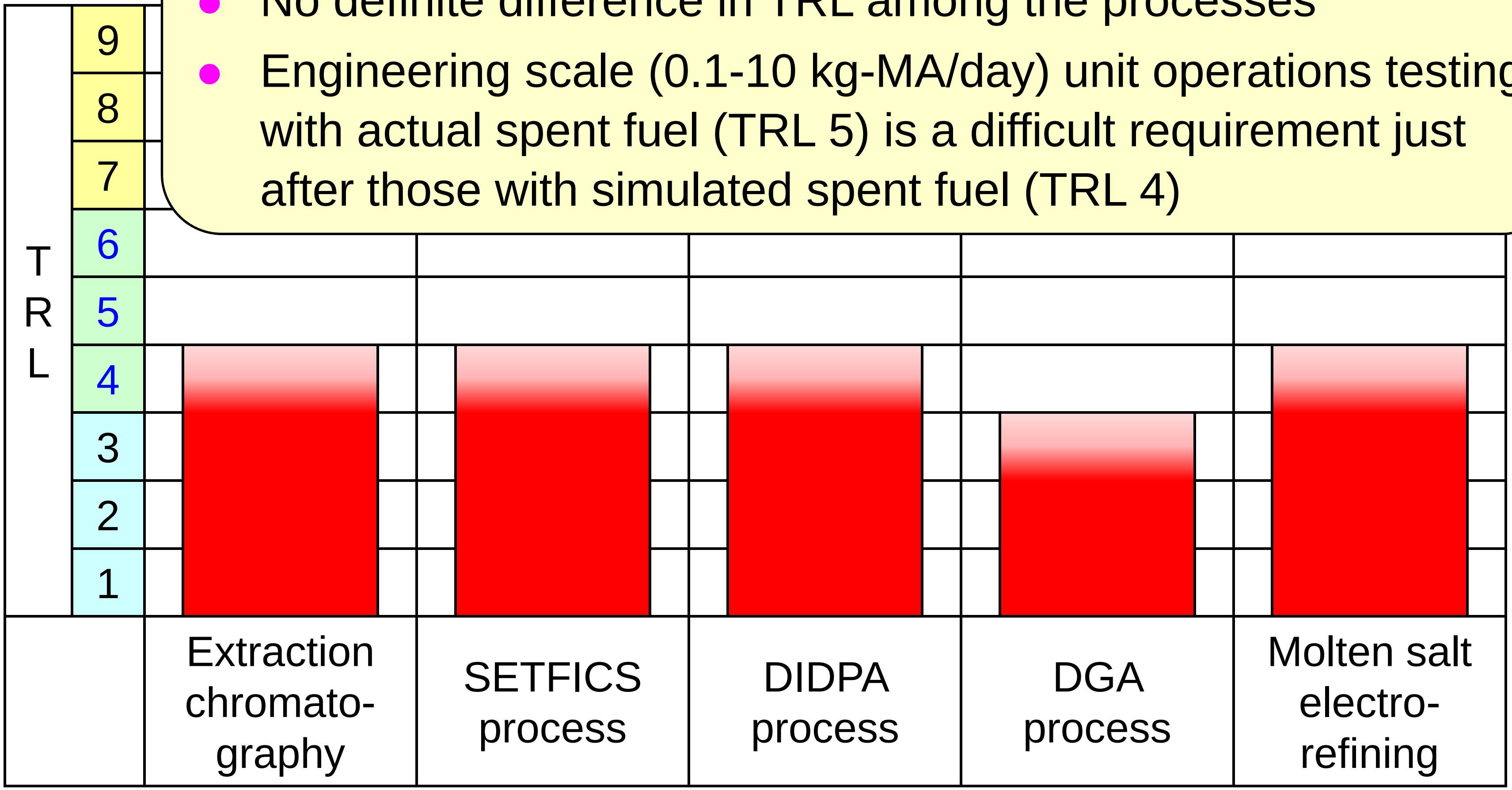
3	Concept Development	*<u>Laboratory-scale</u>* batch testing with *<u>simulated materials</u>* Preliminary testing of equipment design concepts
2		*<u>Bench-scale</u>* batch testing with *<u>simulated materials</u>* Preliminary selection of process equipment
1		Basic principles observed and formulated

TRL for MA Partitioning Processes (2/2)

TRL Evaluation

- Several processes have been developed for MA partitioning
- No definite difference in TRL among the processes
- Engineering scale (0.1-10 kg-MA/day) unit operations testing with actual spent fuel (TRL 5) is a difficult requirement just after those with simulated spent fuel (TRL 4)



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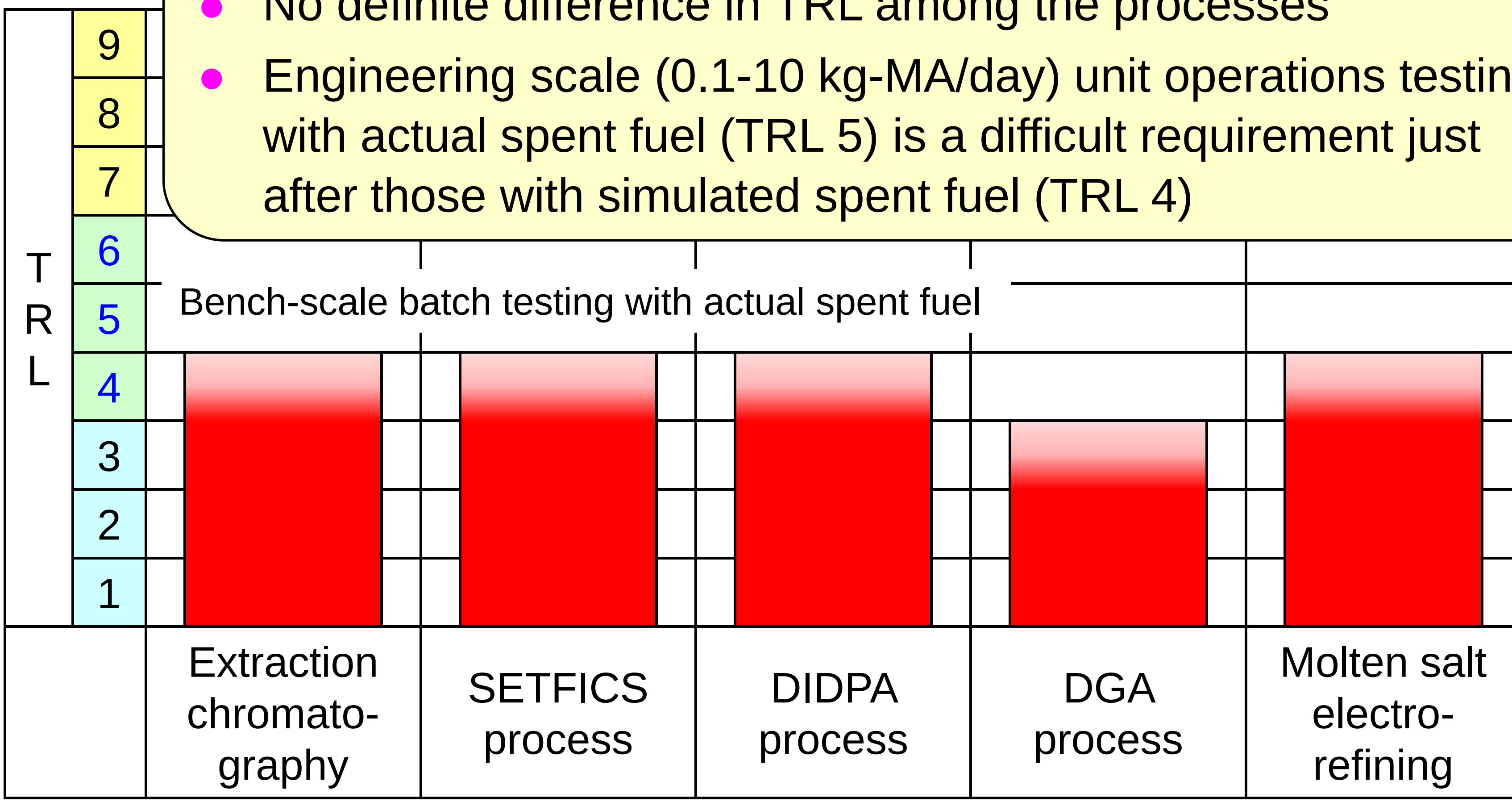

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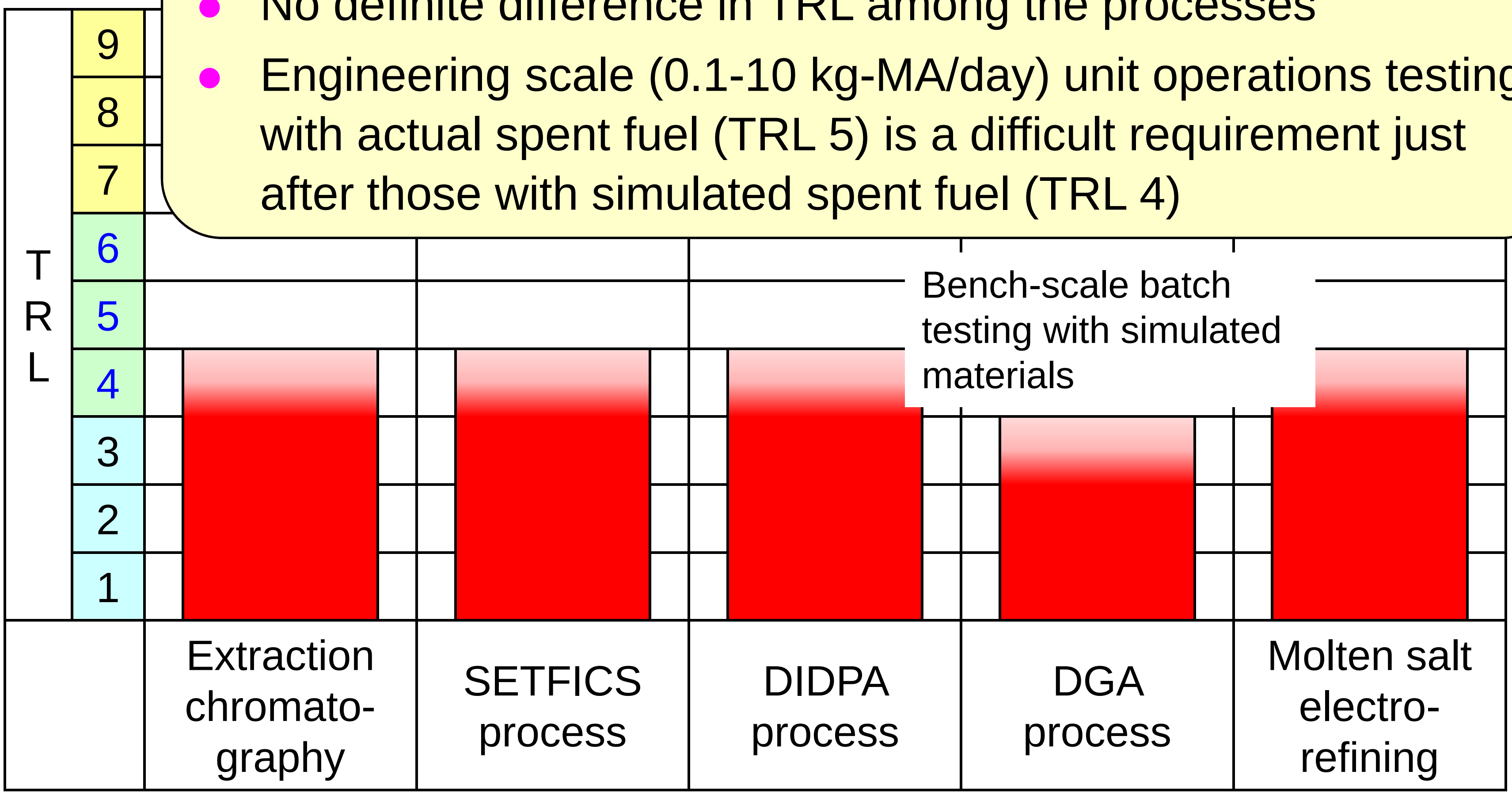

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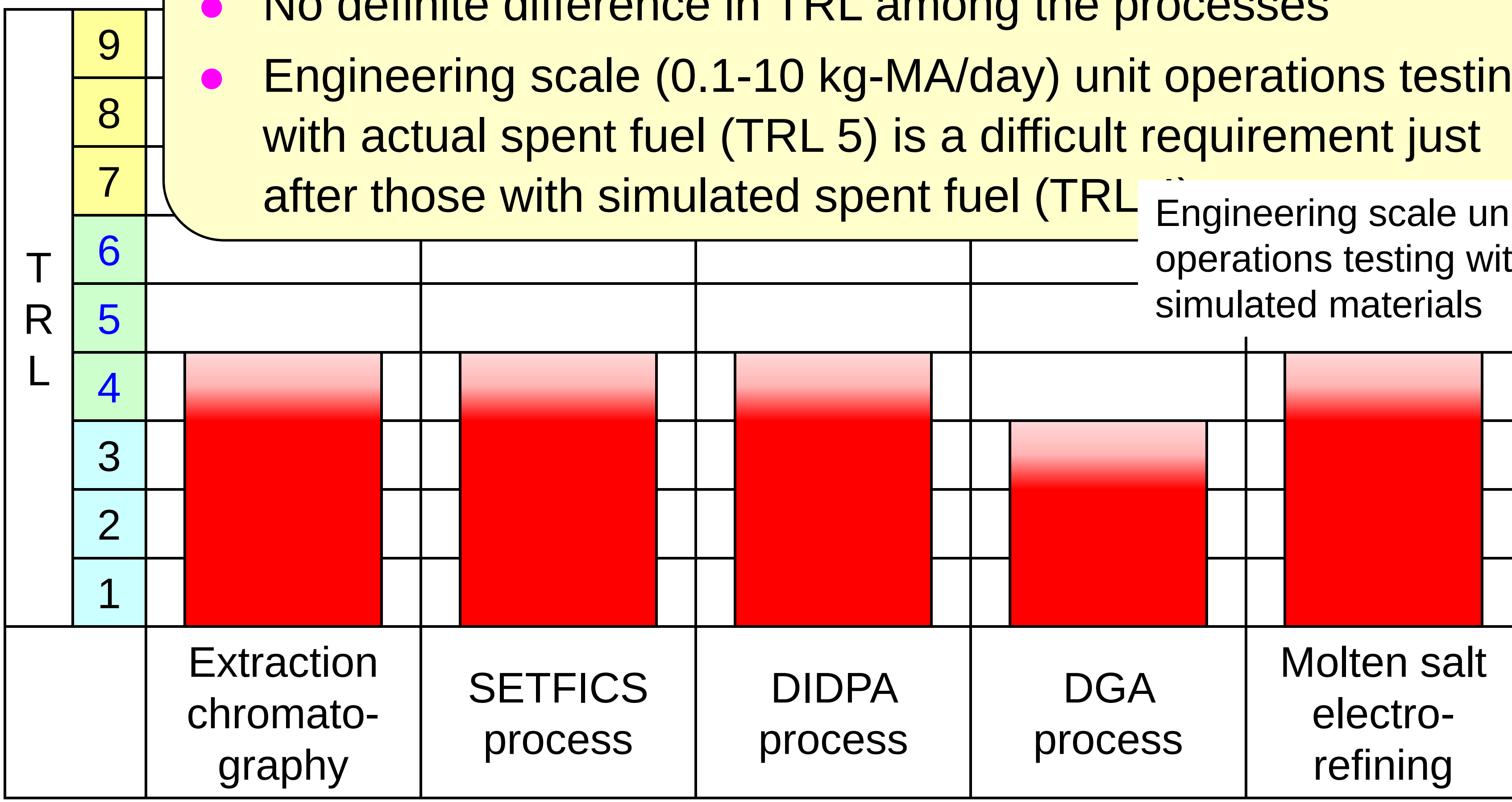

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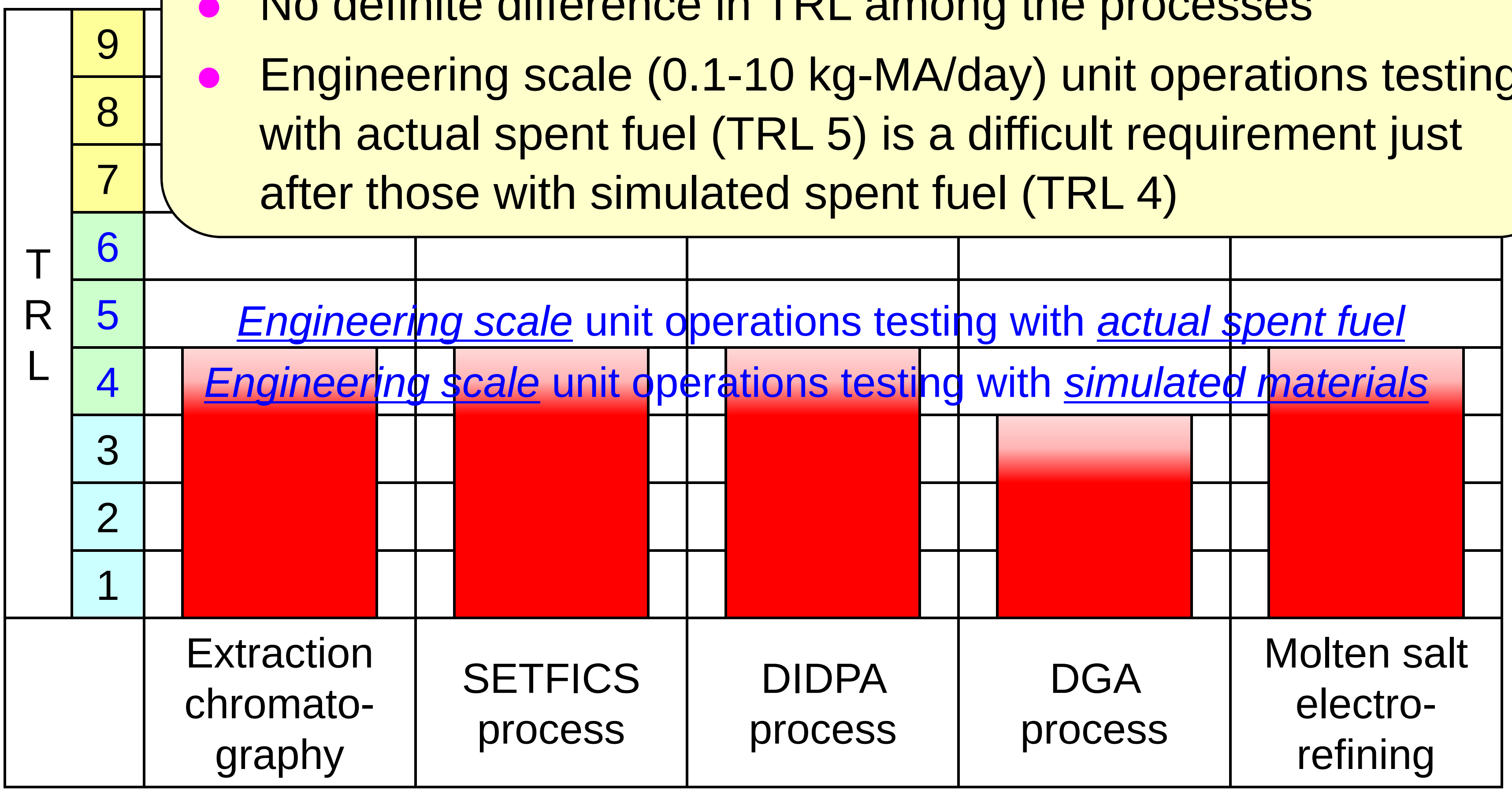


TRL for MA-bearing Fuels (1/2)

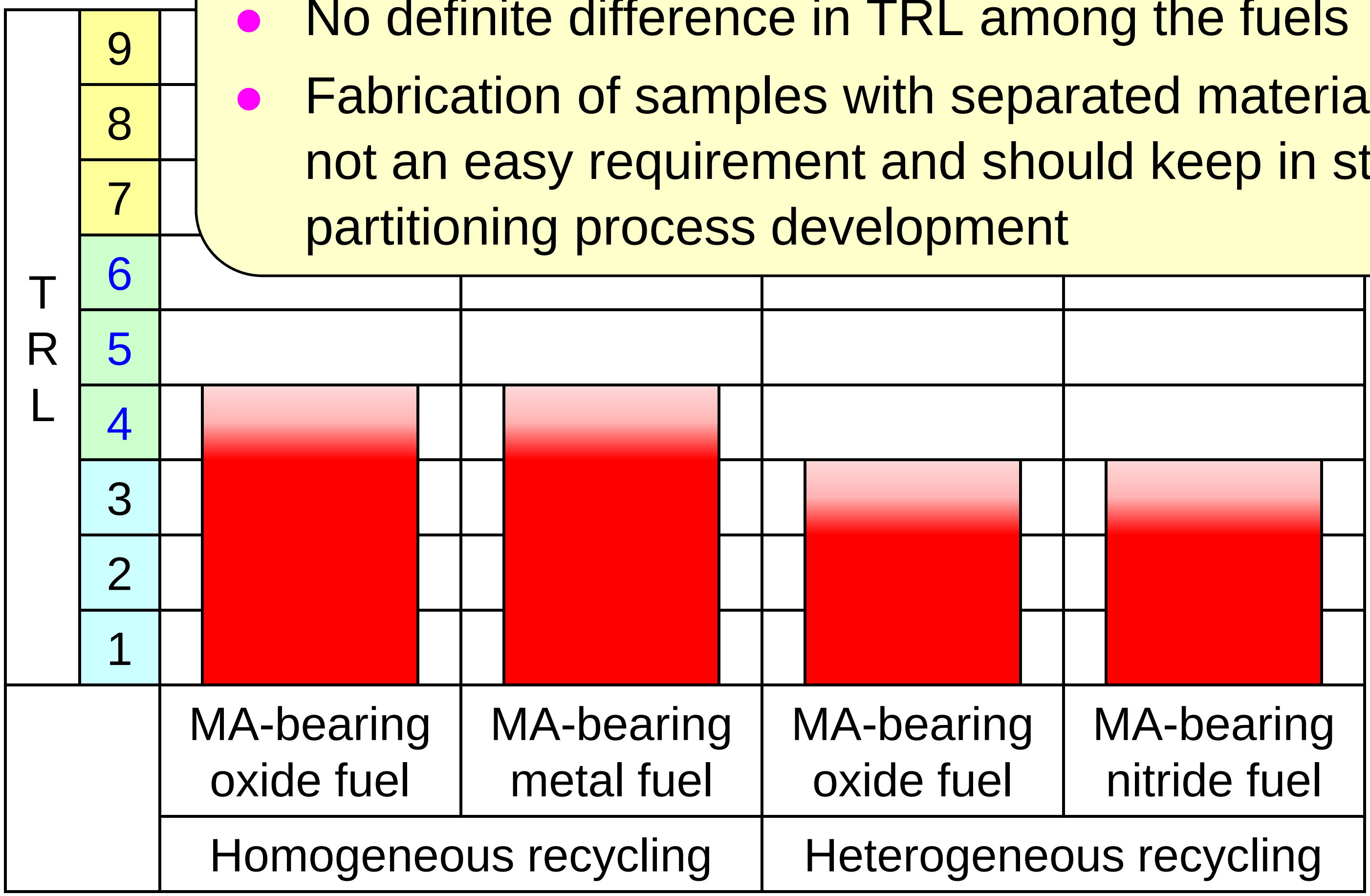
TRL Definitions

TRL	Category	Description
9 :	Proof of Performance	Actual facility proven through successful mission operations :
6	Proof of Principle	Fabrication of *pins* with *separated materials* Irradiation testing of *pins* in prototypic environment
5		Fabrication of *samples* with *separated materials* Irradiation testing of samples in relevant environment
4		Fabrication of *samples* (rodlets, pellets) with *stockpile materials* Irradiation testing of *samples* in relevant environment
3	Concept Development	*Bench-scale* fabrication testing with *surrogates* *Bench-scale* characterization of fundamental properties
2		Fuel candidates selected from options based on performance data on similar systems, based on selection criteria
1		Basic principles observed and formulated

TRL for MA-bearing Fuels (2/2)

TRL Evaluation

- Several types of MA-bearing fuels have been developed
- No definite difference in TRL among the fuels
- Fabrication of samples with separated materials (TRL 5) is not an easy requirement and should keep in step with MA partitioning process development



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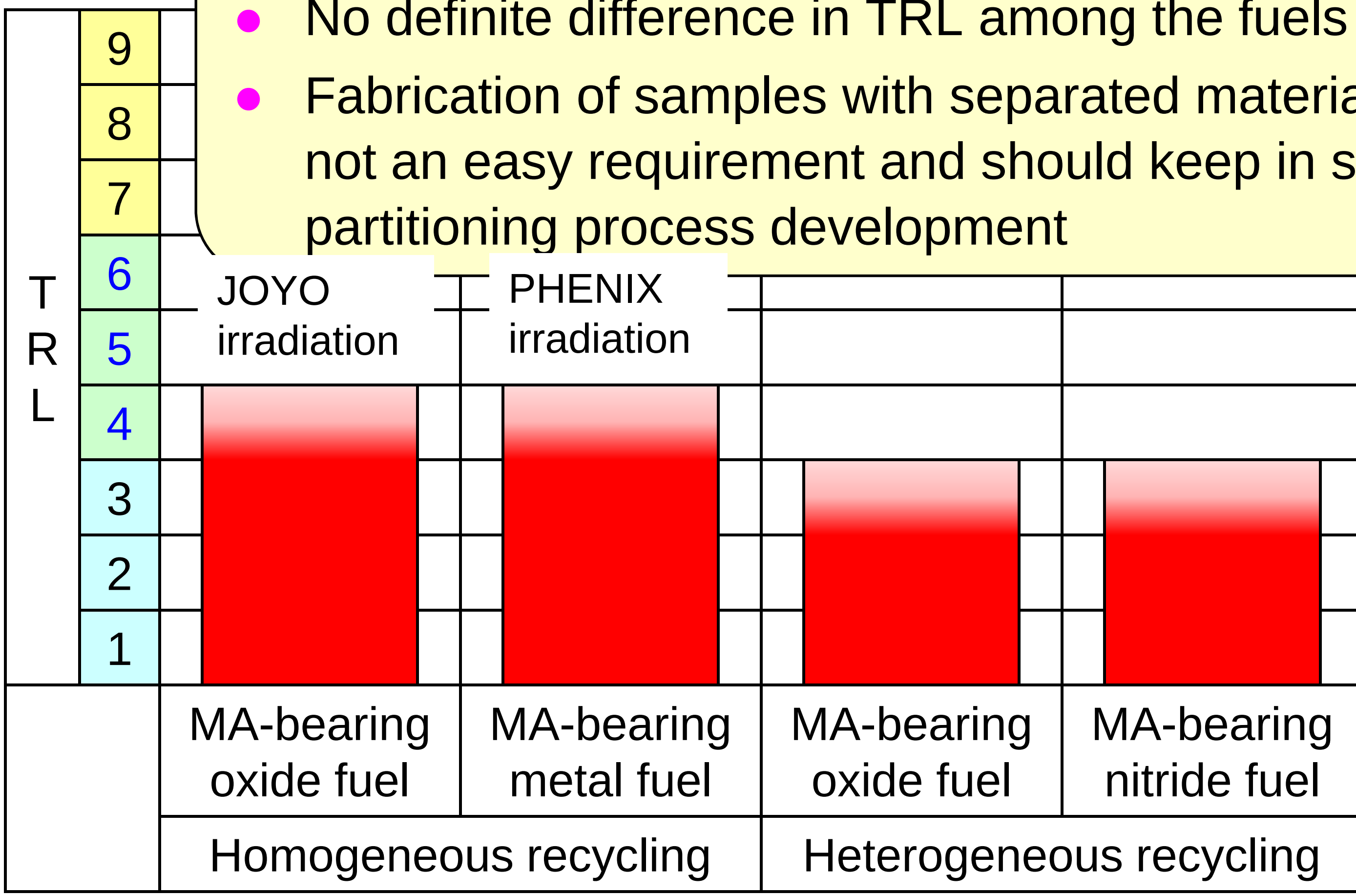

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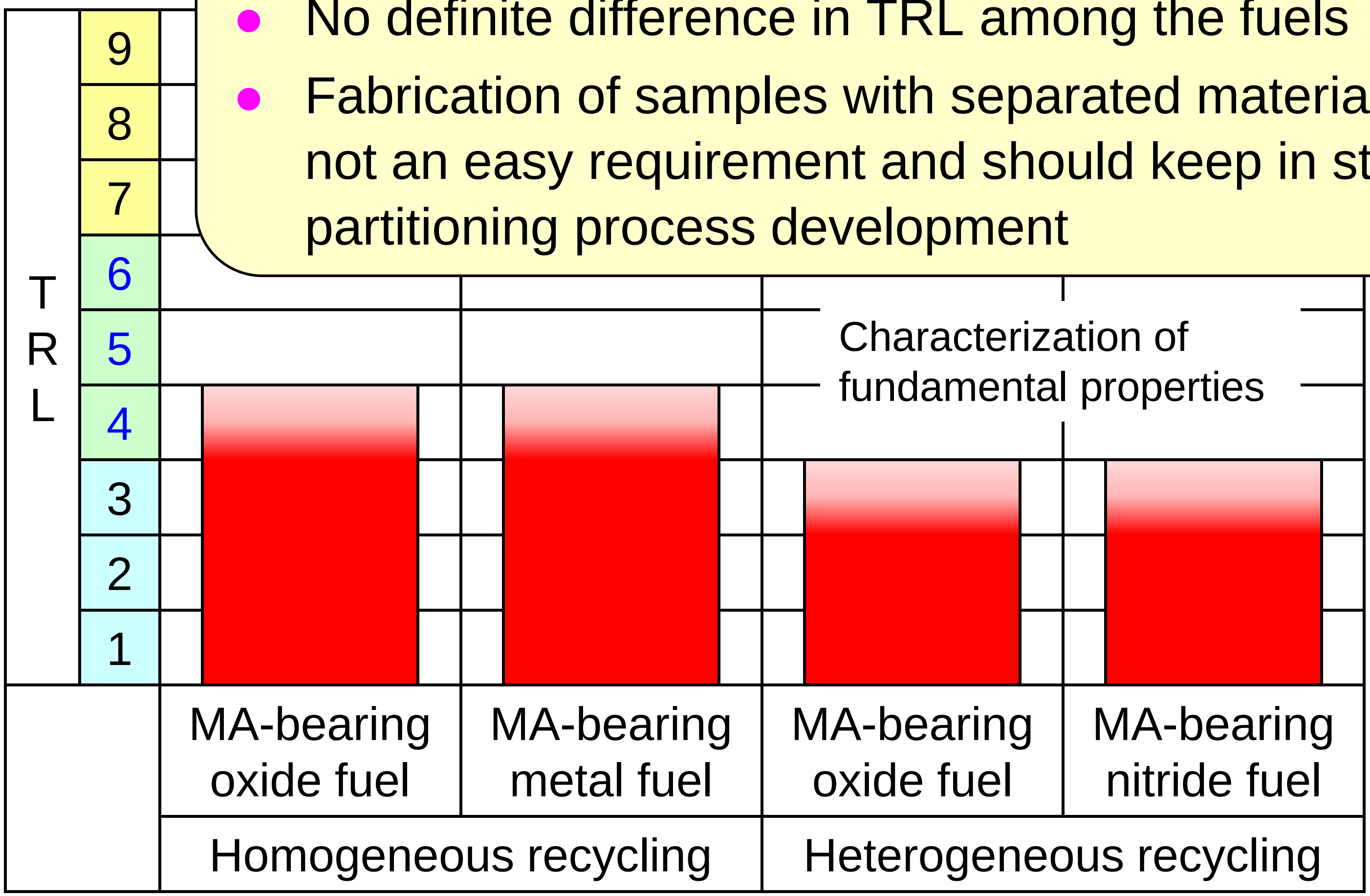

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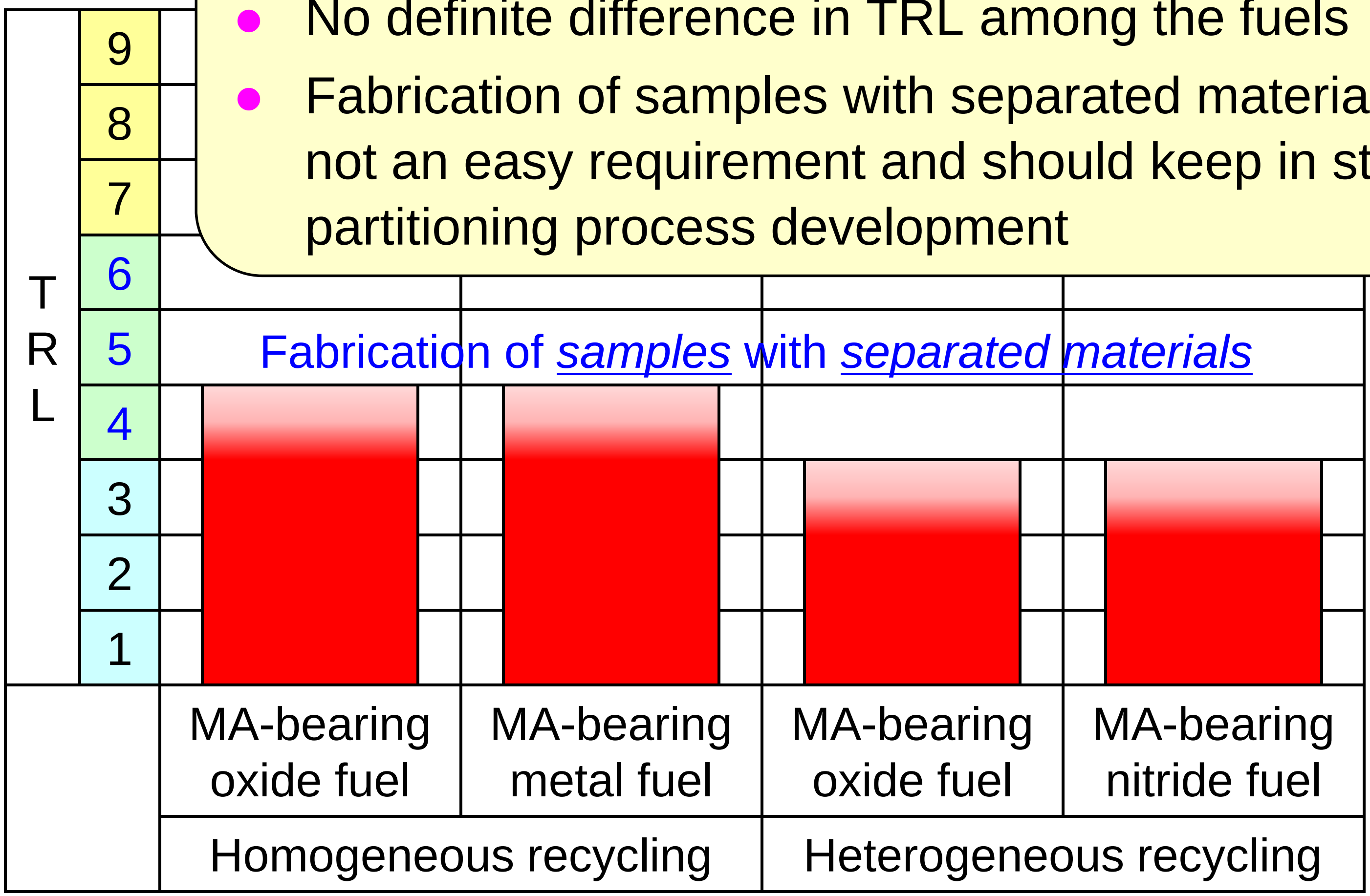


Technology pathway (1/3)

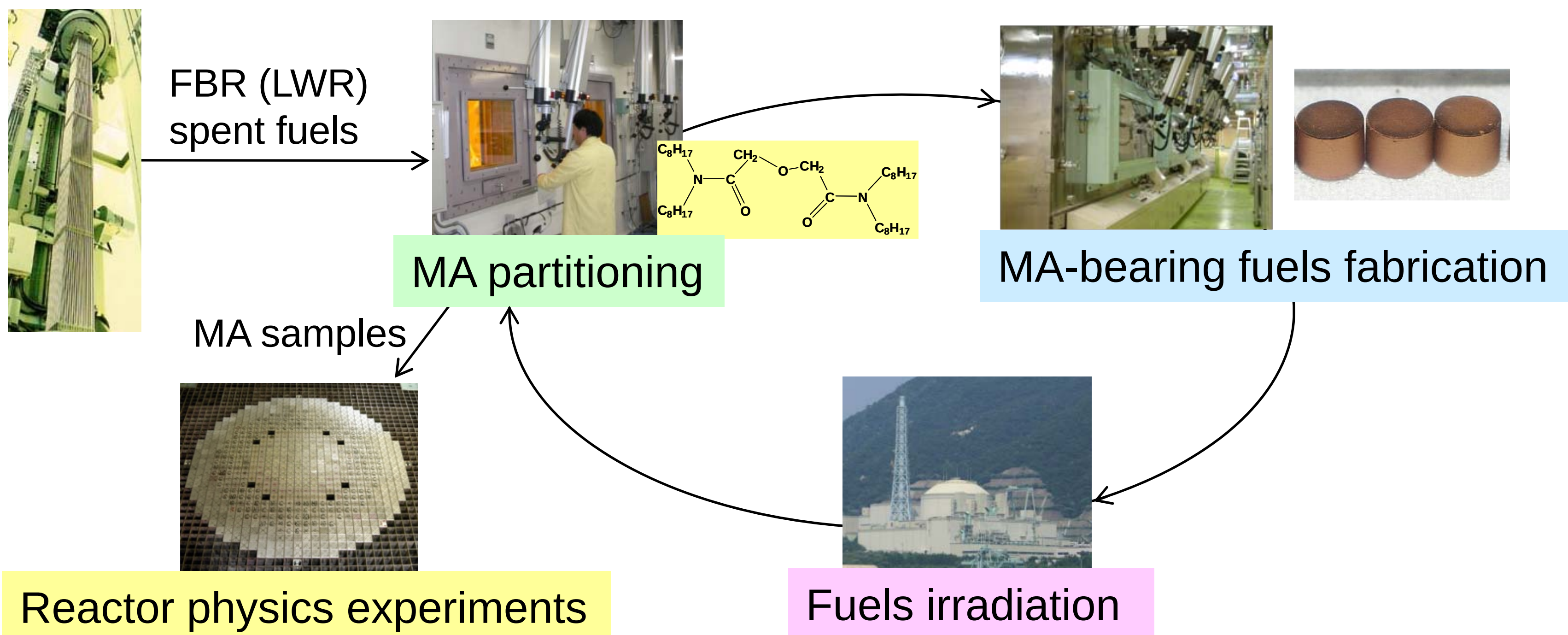
- Through the TRL evaluation, it is recognized that difficult requirements are to be satisfied at TRL 5 in each field
  - » For ADS (and FBR) critical experiment with a large amount of MA and a new experimental facility at *TRL 5*
  - » For MA partitioning process engineering-scale (0.1-10 kg-MA/day) unit operations tests with actual spent fuel at *TRL 5*
  - » For MA-bearing fuels fuel pins-scale (1-100 g-MA/day) fabrication and irradiation tests with actual separated materials at *TRL 5*
- At TRL 5, new equipments and facilities that cost a lot are needed

Technology pathway (2/3)

- Before TRL 5, laboratory-scale tests with actual spent fuel should be thoroughly made
  - » Using existing facilities
  - » With low cost
- Through these laboratory-scale tests
  - » To experience/master MA handling and treatment
  - » To compare/select partitioning processes and fuel types
- After that, TRL 5 should be completed with less cost and shorter schedule

Technology pathway (3/3)

- The introduction of laboratory-scale tests with actual spent fuel for MA partitioning process and with actual separated materials for MA-bearing fuels fabrication and irradiation before the engineering-scale tests (TRL 5) is an effective and efficient solution



Summary

- The technology readiness levels (TRL) were evaluated and the technology pathway was discussed for the systems of FBR and ADS for the minor actinides (MA) transmutation, MA partitioning processes, and MA-bearing fuels.
- Through the TRL evaluation, it is recognized that difficult requirements are to be satisfied at TRL 5 in each field.
- The introduction of laboratory-scale tests with actual spent fuel for MA partitioning process and with actual separated materials for MA-bearing fuels fabrication and irradiation before the engineering scale tests (TRL 5) is an effective and efficient solution.